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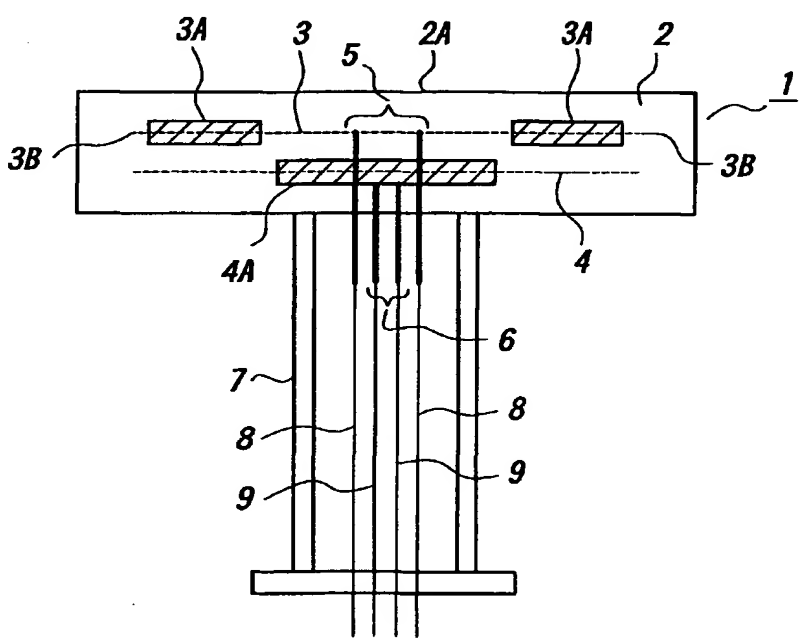
(54) Ceramic heater

(57) A ceramic heater comprising a ceramic substrate having a heating face, and a resistance heat generator buried in the ceramic substrate, wherein the resistance heat generator comprises plural planar resistance heating elements arranged in a layered fashion as viewed in a thickness direction of the ceramic substrate, and each of said plural planar heating elements comprises a heat generation density-increased portion, and the heat generation density-increased portions of the respective plural planar heating elements are located in different portions, respectively.

FIG. 1



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Description

Background of the Invention

(1) Field of the Invention

[0001] The present invention relates to ceramic heater, more particularly ceramic heaters to be favorably used in semiconductor-producing apparatuses such as semiconductor-producing apparatuses and etching apparatuses.

(2) Related Art Statement

[0002] In order to form semiconductor films with a raw material gas such as silane gas by hot CVD or the like, the semiconductor-producing apparatus is provided with a ceramic heat generator for heating wafers as substrates.

[0003] In this ceramic heater, inner and outer resistance heat generators made of a high melting point metal are buried in the ceramic substrate, and separate current-introducing terminals are provided for the respective resistance heat generators. The inner resistance heat generator and the outer resistance heat generator are independently controlled by independently applying voltages to them, respectively. Thus, such a ceramic heater employs a so called two-zone heater structure.

[0004] On the other hand, JP-A 5-326,112 describes that a heat generator of a ceramic heater is constituted by plural circuit patterns made of a high melting point metal, and these circuit patterns are so arranged to compensate defect portions with respect to each other or one another. More specifically, this is realized by overlapping a bent or return portion of one circuit pattern with another circuit pattern.

[0005] However, if the above-mentioned two-zone heater is operated for a long time period, the ceramic substrate and the resistance heat generators are extremely frequently heated and cooled. A difference in coefficient of thermal expansion between the ceramic substrate and the high melting point metal constituting the resistance heat generators causes shearing stress in the current-introducing terminals connected to the resistance heat generators.

[0006] If shearing stress frequently acts upon the current-introducing terminals,

[0007] Further, although the resistance heat generator is generally bonded to the current-introducing terminal with a brazing material, such bonded portions are sometimes broken by shearing stress due to difference in thermal expansion between the resistance heat generator and the brazing material.

[0008] If the current-introducing terminal is cut off from the resistance heat generator like this, current does not flow either the outer resistance heat generator or the inner resistance heat generator, so that no heat generation occurs. Owing to this, a large temperature difference develops between the outer and inner peripheral portions of the ceramic substrate, so that cracking occurs between them to sometimes disable practical use as the ceramic heater.

[0009] In the ceramic heater described in JP-A 5-326,112, when the circuit pattern is constituted by two layers and if the wafer is heated with only one layer with the other circuit being broken, a temperature difference within a plane of the ceramic heater becomes larger. Consequently, cracking occurs within the ceramic heater as mentioned above, so that the heater is sometimes broken.

Summary of the Invention

[0010] It is an object of the present invention to provide a ceramic heater having a new construction free from the above problems.

[0011] The ceramic heater according to the present invention comprises a ceramic substrate having a heating face, and a resistance heat generator buried in the ceramic substrate, wherein the resistance heat generator comprises plural planar resistance heating elements arranged in a layered fashion as viewed in a thickness direction of the ceramic substrate, and each of said plural planar heating elements comprises a heat generation density-increased portion, and the heat generation density-increased portions of the respective plural planar heating elements are located in different portions, respectively.

[0012] So long as the temperature distribution of the ceramic heater can be highly uniform, the heat generation density-increased portions of the respective planar heating elements may be partially overlapping located in different portions, respectively. Therefore, the feature "the heat generation density-increased portions of the respective planar heating elements are located in different portions, respectively" encompasses this overlapped manner.

[0013] Thus for example the respective portions of relatively higher heat energy output rate (heat generation density-increased portions) of the different heating elements may be laterally offset from each other, either with or without partial overlap, as seen looking in plan view on a major face of the heater. In each such heating element the portion or portions of higher heat energy output rate is adjacent a portion or portions of relatively lower heat energy output rate.

Brief Description of the Drawings

[0014] For a better understanding of the invention, reference is made to the attached drawings, wherein:

[0015] Fig. 1 is a sectional view of an embodiment of the ceramic heater according to the present invention.

[0016] Fig. 2 is a sectional view of another embodiment of the ceramic heater according to the present invention.

[0017] Fig. 3 is a figure for illustrating a producing process as an example to produce a ceramic heater according to the present invention.

[0018] Figs. 4(a) to 4(c) illustrate cases where the current-introducing terminal portions 5 and 6 are connected to the outer peripheral portions of the planar resistance heating elements 3 and 4, respectively, substantially in parallel to the planar resistance heating elements through the terminals.

Detailed Description of the Invention

[0019] Fig. 1 is a sectional view of an embodiment of the ceramic heater according to the present invention. In each figure, details are omitted and parts are drawn in different scales for the purpose of clarified explanation.

[0020] As shown in Fig. 1, the ceramic heater 1 according to the present invention comprises a ceramic substrate 2, and an upper planar resistance heating element 3 and a lower planar resistance heating element 4 arranged in a layered fashion as viewed in a thickness direction of the ceramic heater. Current-introducing terminal portions 5 and 6 are provided in a central portion of the ceramic substrate 2.

[0021] The upper planar resistance heating element 3 and the lower planar resistance heating element 4 are arranged substantially in parallel to a heating face 2A of the ceramic substrate 2. The upper planar resistance heating element 3 has a heat generation density-increased portion 3A at an outer peripheral portion, and the lower planar resistance heating element 4 has a heat generation density-increased portion 4A at an inner peripheral portion.

[0022] One end of the current-introducing terminal portion 5 is connected to the upper planar resistance heating element 3, and one end of the current-introducing terminal portion 6 is connected to the heat generation density-increased portion 4A of the lower planar resistance heating element 4. The other end of each of the current-introducing terminal portions 5 and 6 is connected to lead wires 8 or 9, respectively. Thereby, current can be separately introduced to the upper planar resistance heating element 3 and the lower planar resistance heating element 4 from an external electric power source to independently control the heating elements.

[0023] The ceramic substrate 2 is provided with a cylindrical hollow portion 7 at its under portion, which protects the other ends of the current-introducing terminal portions 5 and 6, i.e., those portions of the terminal portions which come out of the ceramic substrate 2.

[0024] Therefore, for example, even if a joint between the upper planar resistance heating element 3 and the current-introducing terminal portion 5 is broken due to a difference in heat expansion between the ceramic heater and the resistance heating element as mentioned above, the entire ceramic substrate 2 can be relatively uniformly heated. Consequently, occurrence of cracking owing to temperature variations in the ceramic substrate 2 can be prevented.

[0025] JP-A 5-326,112 describes the invention in which a plurality of the circuit patterns are merely arranged to compensate their defect portions. To the contrary, according to the present invention, the "heat generation density-increased portions" are provided for the plural planar resistance heating elements, corresponding to the plural circuit patterns in JP-A 5-326,112, at different locations.

[0026] Although the "heat generation density-increased portions" can compensate the defect portions of the planar resistance heating elements as in the same way as JP-A 5-326,112. This compensation is made exclusively by the heat generation density-increased portion, not by the arrangement of the circuit patterns. Further, the heat generation density-increased portion is a completely different concept from that of the arrangement of the plural circuit patterns to mutually compensate their defect portions.

[0027] In the following, the present invention will be explained based on embodiments in connection with the drawings.

[0028] The ceramic heater according to the present invention needs to be provided with a plurality of planar resistance heating elements in a layered fashion as viewed in a thickness direction of the ceramic substrate.

[0029] The ceramic heater 1 shown in Fig. 1 comprises two, i.e., an upper planar resistance heating element 3 and a lower planar resistance heating element 4. However, the number of the planar resistance heating elements is not particularly limited, so long as the above requirements are met. In general, the object of the present invention can be sufficiently accomplished by providing two or three planar resistance heating elements.

[0030] Further, the plural planar resistance heating elements of the ceramic heater according to the present invention need to include their heat generation density-increased portions located in different positions. When the plural planar resistance heating elements include their heat generation density-increased portions like this and for example if the upper planar resistance heating element 3 shown in Fig. 1 does not generate heat, the ceramic substrate 2, and in turn a target object on the heating face 2A can be uniformly heated with much heat from the heat generation density-increased portion of the lower planar resistance heating element 4.

[0031] When the heat generation density-increased portions are provided for the planar resistance heating elements at different positions and when at least two of the plural planar resistance heating elements generate heat, the amount of heat generated from each of the heat generation density-increased portions becomes uniform within the ceramic substrate. Therefore, cracking can be prevented within the ceramic substrate, and the target object can be uniformly heated.

[0032] In the ceramic heater 1 shown in Fig. 1, the upper planar resistance heating element 3 and the lower resistance heating element 4 are arranged substantially in parallel to the heating face 2A of the ceramic substrate 2. By so doing, since heat can be extremely uniformly transmitted in a vertical direction within the ceramic substrate 2, an object to be heated, a silicon wafer, for example, which is placed on a heating face 2A, can be extremely uniformly and effectively heated.

[0033] The wording "substantially in parallel to" encompasses not only "completely parallel" but also a range of -0.5° to 0.5° relative to the complete parallelness.

[0034] In the ceramic heater according to the present invention, variations in the temperature distribution within the heating face of the ceramic substrate are preferably within 50°C and more preferably within 20°C between the maximum temperature and the minimum temperature in case that the heating is effected with each of the planar resistance heating element. If such variation in the temperature distribution within the heating face of the ceramic substrate are suppressed to not more than 50°C between the maximum temperature and the minimum temperature in case that heating is effected with each planar resistance heating element, cracking of the ceramic heater can be more effectively prevented. For example, even if no current flows through the upper planar resistance heating element 3 in Fig. 1 to disable functioning of the heating element 3 as a heater, the substrate can be uniformly heated with the lower planar resistance heating element 4 only. Consequently, cracking due to non-uniform temperature distribution within the ceramic substrate can be more effectively suppressed, and the target object on the heating face 2A can be more uniformly heated.

[0035] In the ceramic heater 1 shown in Fig. 1, a current-introducing terminal portion 5 is connected to the upper planar resistance heating element 3 at a position different from the heat generation density-increased portion 3A. Since the current-introducing terminal portion is to be connected to the heat generation density-increased portion, a relatively large amount of a brazing material is required, so that the connecting portion is likely to be broken owing to a difference in thermal expansion between them. Therefore, when the current-introducing terminal portion is connected as mentioned above, a case where all the connections between the planar resistance heating elements and the current-introducing terminal portions are cut can be prevented.

[0036] Besides the connecting manner of the current-introducing terminal portions to the planar resistance heating elements as shown in Fig. 1, the current-introducing terminal portion 5 may be connected, for example, to an outer peripheral portion 3B of the upper planar resistance heating element 3 in Fig. 1.

[0037] In the ceramic heater 1 in Fig. 1, the current-introducing terminal portions 5 and 6 are arranged to gather in a central portion of the ceramic substrate 2. By so doing, the ceramic heater can be easily placed in a chamber, and the current flowing through a plurality of the resistance heating elements can be controlled with a single thermocouple by appropriately setting the power ratio between them.

[0038] When those portions of the current-introducing terminal portions 5 and 6 which come out of the ceramic substrate 2 are covered with a cylindrical hollow portion 7 provided at the ceramic substrate, those portions can be effectively protected against external impact and corrosive gases.

[0039] Fig. 2 is a sectional view for illustrating another ceramic heater according to the present invention. In Fig. 2, same or similar reference numbers as in Fig. 1 are used for identical or similar parts.

[0040] In the ceramic heater 11 in Fig. 2, a current-introducing terminal portion for an upper planar resistance heating element 3 is constituted by an anode terminal 15A and a cathode terminal 15B. Similarly, a current-introducing terminal portion for an upper planar resistance heating element 4 is constituted by an anode terminal 16A and a cathode terminal 16B. The terminals 15A, 15B, 16A and 16B are arranged in respective side portions such that the anode terminals 15A and 16A are united, and the cathode terminals 15B and 16B are united, whereas the former are separated from the latter. This arrangement of the terminals can suppress the occurrence of discharge between the terminals.

[0041] The same effect as in the case of Fig. 1 can be obtained by the arrangement of the current-introducing terminal portions in the configuration as shown in Fig. 2. In the case of Fig. 2, coverage of the anode terminals 15A and 16A, etc. with a cylindrical hollow portion provided at the ceramic substrate can effectively protect them against the corrosive gases.

[0042] The configuration of the planar resistive heating elements in the ceramic heater according to the present invention is not limited, so long as the object of the present invention can be realized. For example, the ceramic heater may be constituted by a network member, a coil member, a ribbon-shaped member or the like. In order that the ceramic heater may exhibit conspicuous resistance against heating/cooling heat cycles when the ceramic heater is operated, the planar resistance heating element is preferably constituted by the network member or the coil member. Further, the planar shape of the planar resistance heating element is not particularly limited.

[0043] When the planar resistance heating element is to be constituted by the network member, the heat generation density-increased portion is formed by knitting wires at a higher density at a given location or reducing the sectional area of the wire constituting the network member at a given location.

[0044] When the planar resistance heating element is to be constituted by a coil, the heat generation density-increased portion can be formed by increasing the number of windings or the pitch at a given location or by

increasing the diameter of concentric turns of the coil at such a given location.

[0045] When the planar resistance heating element is to be constituted by the ribbon-shaped member, the heat generation density-increased portion can be formed by reducing the width of the ribbon at a given location.

[0046] The ceramic substrate in the present invention may be produced from a known ceramic material selected from nitride ceramics such as aluminum nitride, silicon nitride, boron nitride and sialon and known ceramic materials such as an alumina-silicon carbide composite material. However, in order to provide the ceramic heater of the present invention with high corrosion resistance against the corrosion gases such as halogen-based gases when the heater is assembled into a semiconductor-producing apparatus or the like, use of aluminum nitride is preferred.

[0047] As the planar resistance heating element, high melting point metals such as tantalum, tungsten, molybdenum, platinum, rhenium, hafnium and alloys thereof may be preferably used. Particularly, if the ceramic substrate is constituted with aluminum nitride, molybdenum or a molybdenum alloy is preferred.

[0048] Besides the above-mentioned high melting point metals, conductive materials such as carbon, TiN and TiC may be used.

[0049] For example, the ceramic heater shown in Fig. 1 is produced as follows.

[0050] Fig. 3 is a flowchart showing an example of a method for producing the ceramic heater according to the present invention shown in Fig. 1.

[0051] A powdery ceramic material such as aluminum nitride to constitute the ceramic substrate 2 is preliminarily mixed with a binder by a trommel or the like, the resulting mixture is granulated by a spray granulator.

[0052] Then, as shown in Fig. 3(a), the resulting granulated material is charged a space defined by a mold 21, a lower punch 22 and an upper punch 23, and a first preliminarily molded body 24 is obtained by uniaxial press molding.

[0053] Thereafter, as shown in Fig. 3(b), a network-shaped conductive member 3M to constitute the upper planar resistance heating element 3 and first members 5M to constitute the current-introducing terminal portion 5 are placed on the first preliminarily molded body 24, and the granulated material 25 is charged on the conductive member 3M and the first preliminarily molded body 24 so that the surrounding of the first members 5M may be filled with the granulated material.

[0054] Next, as shown in Fig. 3(c), the resultant is uniaxially press molded with the mold 21, the lower punch 22 and the upper punch 23, thereby forming a second preliminarily molded body 26.

[0055] Then, as shown in Fig. 3(d), a network-shaped conductive member 4M to constitute the lower planar resistance heating element 4 and members 6M to constitute the current-introducing terminal portion 6 are placed on the second preliminarily molded body 26, and second members 5N to constitute the current-introducing terminal portions 5 are placed on the first members 5N, respectively. Then, the granulated material 25 is charged on the conductive member 4M and the second preliminarily molded body 26 so that the surrounding of the members 6M and the second members 5N may be filled with the granulated material.

[0056] Next, as shown in Fig. 3(e), the resultant is uniaxially press molded with the mold 21, the lower punch 22 and the upper punch 23 in the same manner as above, thereby forming a molded body 27.

[0057] Thereafter, although not shown in the flowchart, the thus obtained molded body 27 is subjected to an ordinary hot press, thereby obtaining a sintered body. The ceramic heater 1 as shown in Fig. 1 or 2 can be finally obtained by attaching the cylindrical hollow portion 7 and the lead wires to the sintered body by mechanical tightening, brazing joint, glass joint, a diffusion joint or the like.

[0058] The molding pressure under which the first molded body is obtained as well as the sintering condition in the hot press are arbitrarily set depending upon the kind and the particle diameter of the ceramic material, the finish dimension, etc.

[0059] As mentioned above, although concrete explanation has been made with respect to the embodiments of the ceramic heaters according to the present invention as shown in Figs. 1 and 2, the ceramic heater is not limited to the above-mentioned embodiments, but any variations and modifications may be made so long as they fall outside the scope of the claimed invention.

[0060] For example, the heat generation density-increased portion of the upper planar resistance heating element and that of the lower planar resistance heating element may be formed at inner and outer peripheral portions, respectively.

[0061] Further, at least one of the plural current-introducing terminal portions may be connected to the outer periphery of the planar resistance heating element substantially in parallel to the planar resistance heating element. Figs. 4(a) to 4(c) illustrate cases where the current-introducing terminal portions 5 and 6 are connected to the outer peripheral portions of the planar resistance heating elements 3 and 4, respectively, substantially in parallel to the planar resistance heating elements through the terminals.

[0062] As mentioned above, according to the ceramic heater of the present invention in which the plural resistance heating elements are arranged to uniformly heat objects to be heated, such as semiconductor wafers, no crack is formed even if a part of the resistance heating elements is broken. Consequently, the ceramic heater which can be stably operated can be offered.

Claims

1. A ceramic heater comprising a ceramic substrate having a heating face, and a resistance heat generator buried in the ceramic substrate, wherein the resistance heat generator comprises plural planar resistance heating elements arranged in a layered fashion as viewed in a thickness direction of the ceramic substrate, and each of said plural planar heating elements comprises a heat generation density-increased portion, and the heat generation density-increased portions of the respective plural planar heating elements are located in different portions, respectively.

2. The ceramic heater set forth in claim 1, wherein the planar resistance heating elements are arranged substantially in parallel to the heating face of the ceramic substrate.

3. The ceramic heater set forth in claim 1 or 2, wherein when the ceramic heater is heated with any one of said planar resistance heating elements, variations in a temperature distribution within the heating face of the ceramic substrate are not more than 50°C.

4. The ceramic heater set forth in any one of claims 1 to 3, which further comprises plural current-introducing terminal portions and wherein said current introducing terminals are connected to said plural planar resistance heating elements, respectively, and at least one of said plural current-introducing terminal portions is connected to the planar resistance heating element at a portion different from the heat generation density-increased portion.

5. The ceramic heater set forth in claim 4, wherein at least one of said plural current-introducing terminal portions is connected to an outer peripheral portion of said plural resistance heat generation elements and substantially in parallel to the planar heat generation element.

6. The ceramic heater set forth in claims 4 or 5, wherein said plural current-introducing terminals are arranged in such a manner that they pass through a portion of the ceramic substrate in a collected manner.

7. The ceramic heater set forth in claim 6, wherein said ceramic substrate further comprises a cylindrical portion wherein at least a part of said plural current-introducing terminals portions are arranged inside the cylindrical hollow portion.

8. The ceramic heater set forth in claim 4 or 5, wherein each of said current-introducing terminal portions comprises an anode terminal and a cathode terminal, the anode terminals of said plurality current-introducing terminal portions are separated from the cathode terminals of said plural current-introducing portions, and each of the anode terminals and the cathode terminals are arranged in such a manner that they pass through a portion of the ceramic substrate.

9. The ceramic heater set forth in claim 8, wherein said ceramic substrate further comprises plural cylindrical portions wherein at least a part of said plural anode terminals and at least a part of said plural cathode terminals are arranged inside the cylindrical hollow portions, respectively.

10. The ceramic heater set forth in any one of claims 1 to 9, wherein each of the planar resistance heating elements comprises a network member or a coil spring-shaped member.

FIG. 1

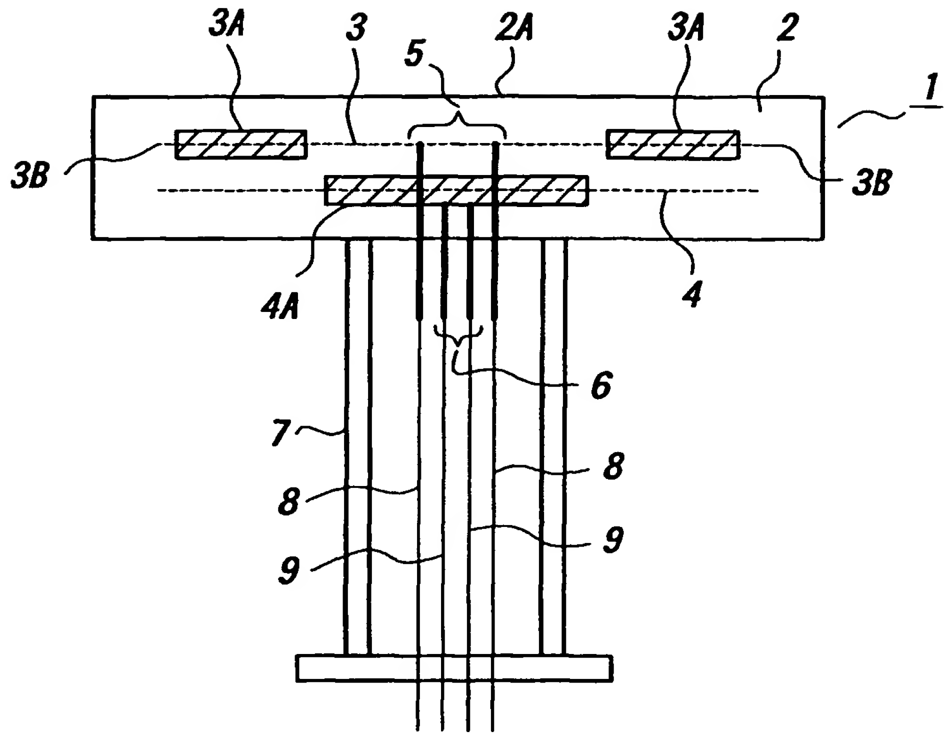
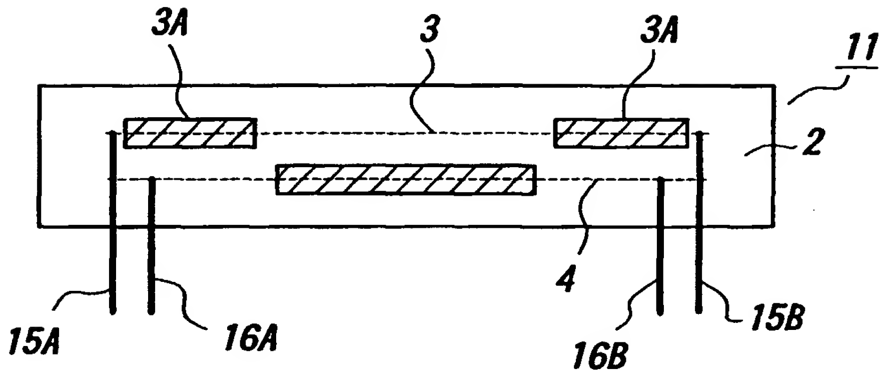


FIG. 2



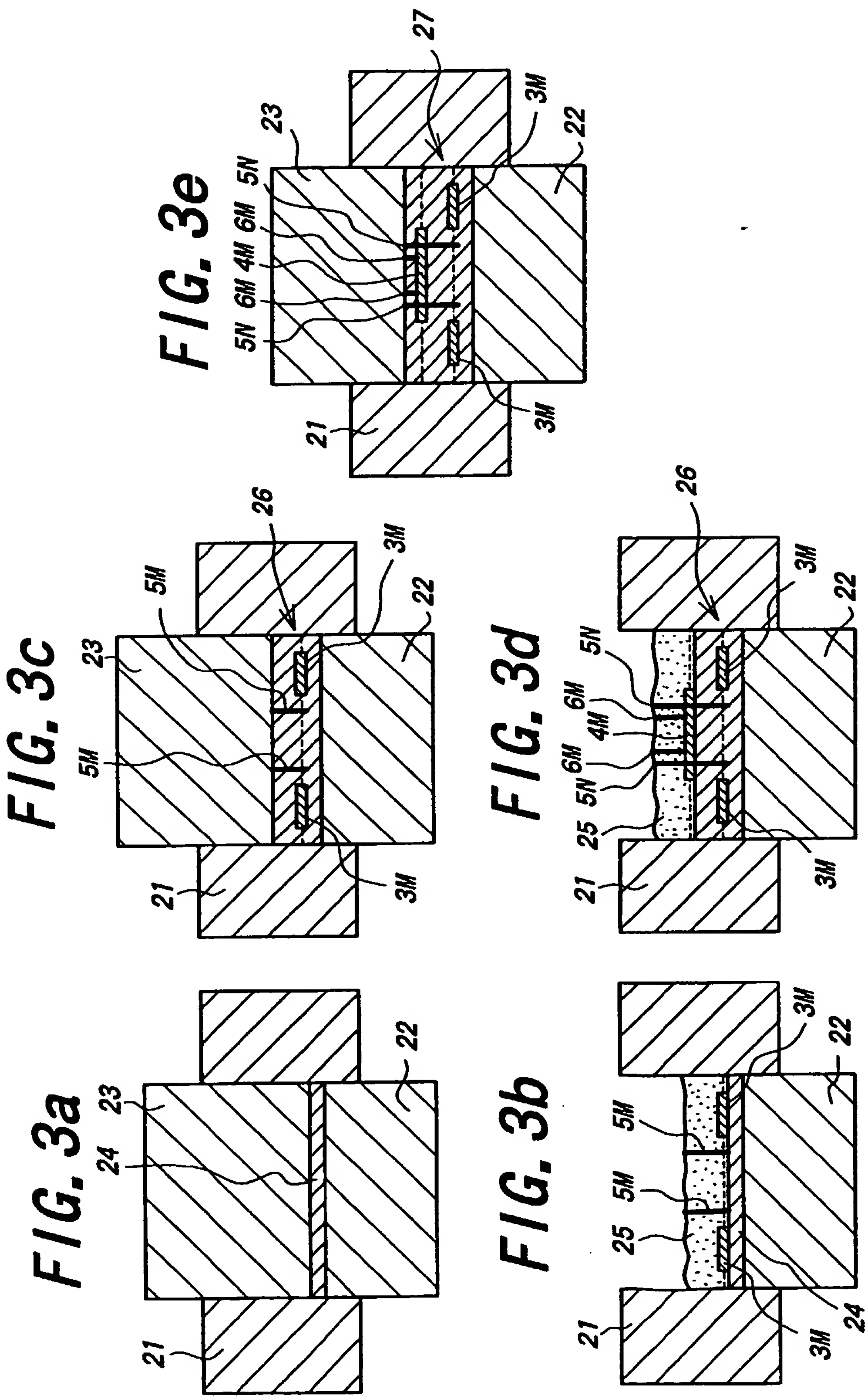


FIG. 3a

FIG. 3b

FIG. 3c

FIG. 3d

FIG. 3e

FIG. 4a

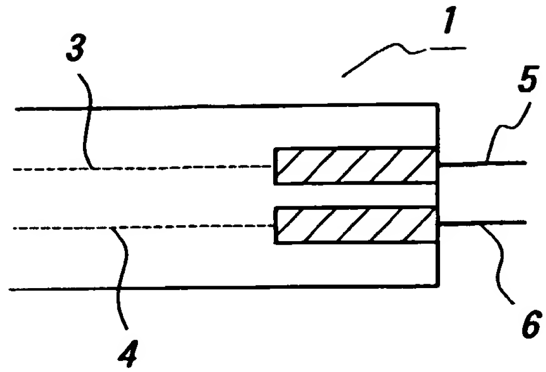


FIG. 4b

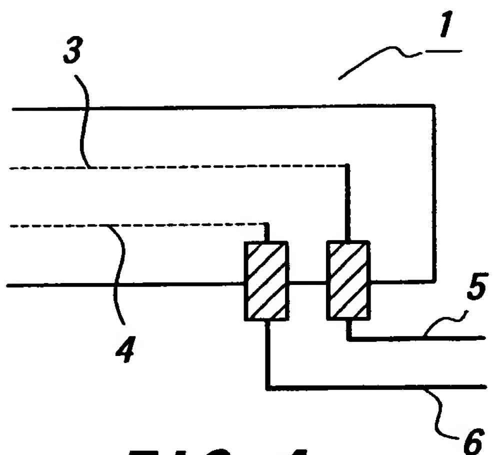


FIG. 4c